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Current Status and Future Prospect of Gas Distributed Generation in Shanghai

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Abstract

In recent years, as a supplement for conventional large-scale power generation system, gas distributed generation has got much comprehensive attention. This study reviews the current status, incentive policies and barriers of gas distributed generation in Shanghai. Currently, the gas distributed energy development in Shanghai is facing grim situations: on the one hand, most of the prime movers are imported from abroad with relaitvely high initial cost, and the natural gas price increases gradually, which lead to the poor economic performance; on the other hand, the relevant institution, mechanism and policy frameworks are imperfect, making gas distributed energy system difficult to fully enjoy its energy saving advantages. However, considering the huge market potential in Shanghai and successful experiences in some foreign countries, it is believed that gas distributed generation will be paid more and more attention, and support the low-carbon transition of the electric power industry in Shanghai.

Keywords: Gas Distributed Generation; Current Status; Future Prospect; Shanghai

1. Introduction

As the typical representative of the so-called second-generation energy system,

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the gas distributed generation is based on the principle of "grade correspondence, temperature conformance, and cascade utilization" [1]. By integrating and optimizing the system components, while considering rational use of energy and reasonable arrangement of energy flow in order to meet cooling, heating and electricity demands simultaneously, the overall efficiency of the total energy system can be enhanced. Currently, the gas distributed generation has become the newest direction of the world's energy development and the key point of the Chinese medium and long-term energy strategy, as well as the focus of clean power generation in Shanghai [2].

The gas distributed generation was firstly introduced in the United States in the late 1970s. During the past 30 years, gas distributed generation has experienced great development in the United States, Japan, Denmark, the Netherlands and other countries, where gas distributed generation plays a major role in energy conservation and emissions reduction activities. In China, gas distributed generation was introduced at the end of last century. However, it groped in the dark for a long time, and failed to form guiding policies and regulations. In October 2011, National Development and Reform Commission, Ministry of Finance, the Ministry of Housing, Energy Board jointly issued the "Guidance on developing natural gas distributed energy", which firstly advocates the gas distributed generation development from the national level [3-4].

Throughout the history of gas distributed generation development in China, Shanghai always plays the leading role. In 1998, Huangpu Central Hospital built the first cooling, heating, and power system, which opened the gate of gas distributed generation development in China [5-6]. In 2004, five departments including Shanghai municipal development and reform commission (NDRC) jointly issued the "Opinions about encouraging the development of gas-fired air conditioning and distributed energy system in Shanghai", which was the first policy about the development of distributed energy system in China; in 2008, Shanghai introduced the second round incentive policy. In 2013, Shanghai government issued the latest "Special measures to support the development of gas distributed energy system and gas-fired air conditioning in Shanghai", establishing a series of relevant incentive policies. In addition, "Twelfth five-year plan of energy development in Shanghai" explicitly proposed to develop regional cogeneration and distributed energy system, and decided to increase the capacity of cogeneration to 2 million kW and install 50 to 60 gas distributed energy systems by 2015.

On the technical level, the Shanghai construction and traffic committee issued the "Engineering technology regulations of the distributed energy system" in 2005, which was the first technical specification of gas distributed generation in China. On the application level, although special support policies have been issued for more than 10 years, the development of the gas distributed generation is still not satisfied.

In summary, Shanghai is always leading the development of gas distributed generation in China from either policy or technical viewpoint. However, present situation suggests that the existing policies and mechanisms are not strong enough to promote rapid development of gas distributed generation in Shanghai. The main reasons can be summarized as the following two points [7-9]:

(1) Existing theory for gas distributed generation is not sufficient to support the benefit distribution in the market oriented economy framework

Theory analysis framework of the gas distributed generation is not perfect in China. Most of existing construction mechanism and grid-connecting policy references that for traditional centralized power plants, and fails to give full consideration the strong coupling characteristic of the supply side and demand side. This situation makes the gas distributed generation become a "heterogeneous" in the current market oriented economy framework.

(2) Existing policies and economic environment are not sound enough to support the development of gas distributed generation

Although Shanghai has introduced a series of subsidies to promote the development of gas distributed generation, these policies fail to enhance its competitiveness fundamentally so as to adapt to developing needs of the market economy. Therefore, the gas distributed generation is still in the state of government support and lack of the independent survived ability in Shanghai. Existing policies and mechanisms are insufficient to support the sustainable development of the gas distributed generation.

At present, Shanghai has put forward the strategic goal to construct a low-carbon and energy-saving global city. As one of the key directions of Shanghai's clean energy development, promotion and application of gas distributed generation is the important guarantee to achieve this goal. Therefore, it is necessary to examine the developing theory and policy of gas distributed generation, to exploit new ideas and new patterns of gas distributed generation development.

2. Current status of gas distributed generation in Shanghai

2.1 Project overview

As of 2014, the total number of gas distributed energy projects is 31 in Shanghai, with total installed capacity of 54322 kW, nearly 0.27% of total installed capacity in Shanghai, and the average installed capacity is about 1752 kW (Fig. 1).

The projects include hospital, hotel, office building, factory, transportation hub, large blocks, etc.; that prime movers include micro and small gas turbine, internal

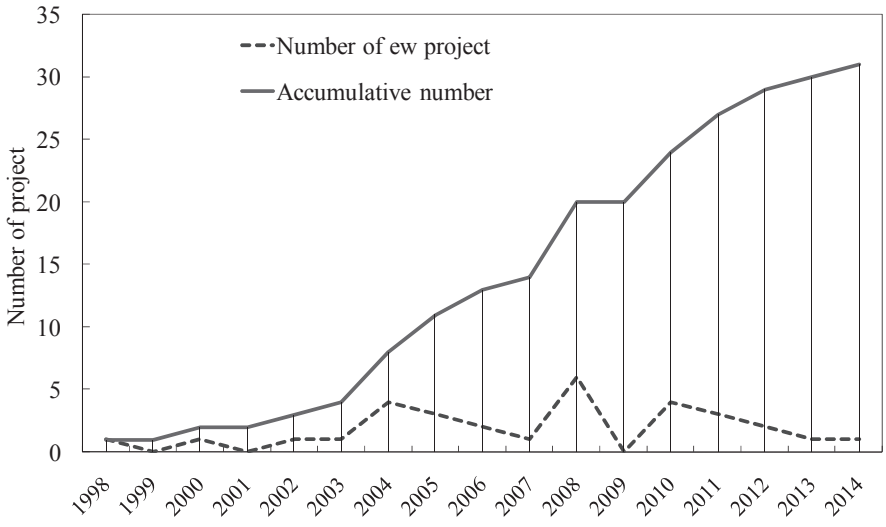

Fig. 1. Number of distributed generation projects in Shanghai

combustion engine and Stirling engine, etc.; and the system design consists of combined heating and power and combined cooling, heating and power. Furthermore, the increment of the installed capacity in recent years mainly comes from regional distributed energy projects, such as the Hongqiao business district and international tourist resort. This also shows that applications of gas distributed generation in Shanghai has transformed from building type to area type.

2.2 Operation information

At present, there are 13 projects under normal operation, the total capacity is 21641 kW, accounting for about 40% of total installed capacity of all projects; there are 4 projects for teaching experiment, the total installed capacity is 275 kW; 5 projects have been stopped, and the total installed capacity is 2258 kW, accounting for about 4% of total installed capacity. The main reasons for shutting down include the inaccuracy load forecast, out of business, municipal movements and biogas drying up.

In addition, the operation status of the project under operation is also diverse. Operation hours of some projects are high and their running efficiency is relatively good. However, operation hours of some projects are very short, so economic efficiency of these projects is low. Fig. 2 is the operation time variation of some projects under normal operation.

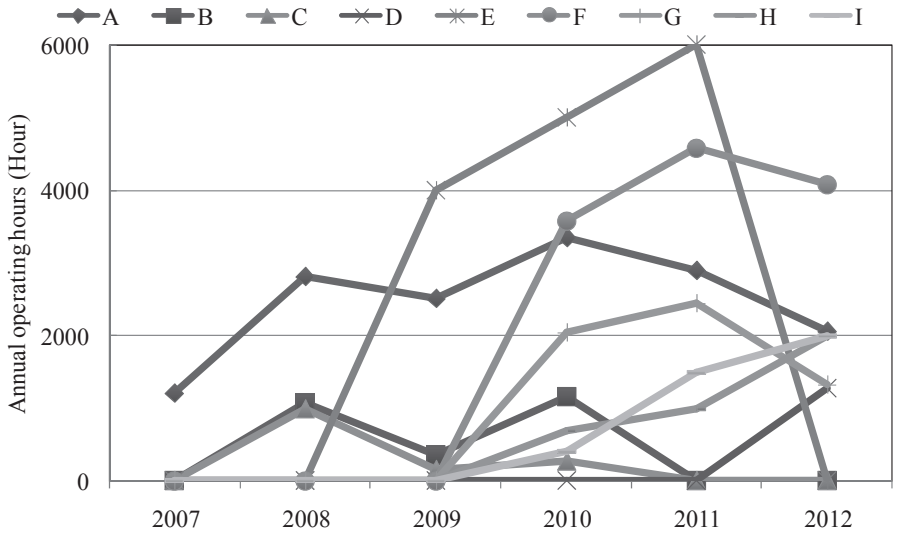

Fig. 2. Annual operating hours of various distributed generation in Shanghai

3. Incentive Policy for gas distributed generation in Shanghai

The Shanghai government always pays enough attention to the development of gas distributed energy system, and has introduced three rounds of incentive policies in the past few yeas.

3.1 The subsidy of equipment investment

According to the third round of policy, the subsidy for equipment investment is given by 1000 RMB/kW for gas distributed generations which are built in hospitals, hotels, factories, shopping malls, business buildings,,-comprehensive business centers and other buildings, industrial parks, large transport hub, tourism resort district, business district and etc. Furthermore, if the annual overall efficiency is larger than 70% and annual utilization hours is more than 2000 hours, addition 2000 RMB/kW will be available, while the highest subsidy of each project is 50 million RMB.

3.2 Discounted natural gas price

In 2005, the Municipal Development and Reform Commission and the Municipal Price Bureau established preferential gas price for gas air conditioning and gas distributed energy system. The gas price for distributed energy supply system is 2.04 RMB/m^3 in 0-80000 m^3/month and 1.94 RMB/m^3 above 80000 m^3 /month in November 2005.

At present, the gas price for distributed energy system implemented by Shanghai is the lowest price in all types of users, which is approximately 64% to 68% of benchmark contract sales price of the same grade industrial users and battalion regiment users.

3.3 Grid-connecting policy

For the distributed energy system which conforms to "Engineering technology regulations of the distributed energy system" and is designed following the heat tracking principle, the grid enterprise must accept its grid connecting according to relevant regulations and sign grid connecting agreement with the investor, and actively provide related services.

4. Barriers against gas distributed generation development in Shanghai

At present, gas distributed energy projects in Shanghai are mainly driven directly by the government, and few are invested by the market. If these problems can't be settled timely, the gas distributed generation is difficult to enter the market, and its development will be severely obstructed.

The main impediment for the development of distributed generation projects is that they usually enjoy energy saving benefits but cost much more money. The gas distributed energy supply system has great social benefits of energy conservation and emissions reduction, but little or no investment benefit for the enterprise, so it is difficult to attract business investment. The main obstacles can be analyzed from the following three aspects for the development of distributed energy system.

4.1 Institutional barriers

(1) The influence of the existing grid-connecting and the electricity sale system

Because of the small capacity of gas distributed generation, its stability is poor when it is operated as an independent power generation system and thus must be connected to the power grid. On the other hand, when the gas distributed energy system is out of operation, the utility grid should be employed to supply the electricity demand.

Driven by its self-interest, the power grid enterprise does not allow the distributed energy system to connect to the power grid. Even it is allowed to connect to the power grid, it must pay a lot of fee for the system engineering and safety protection equipment according to regulations of Shanghai electric power company.

(2) The imperfection of laws and regulations for gas distributed generation

Combined cooling, heating and power system is one of the most important form of the gas distributed generation. In our country, traditional large-scale power grid and large power supply has been the dominant thoughts for a long time. Compared with the development of gas distributed generation, cogeneration and district heating in developed countries, China has no relevant laws and regulations to determine the rule of distributed energy system, and to systematically regulate heating and cooling load planning and industry development planning, and never make mandatory regulations on adopting the way of distributed energy system for the heating and cooling users.

(3) The influence of feed-in tariff determining system

At present, both the feed-in tariff of power generation enterprises and sales price of power grid enterprises are determined by the government. The power plant cannot negotiate price with the terminal users and change power price at will. As to the gas distributed generation system, the high self-use electricity price makes return on investment be high and the low self-use electricity price makes return on investment be low within the current pricing system. Therefore, the development of the gas distributed generation is constrained for the following reasons: firstly, the sales of redundant electricity from the gas distributed generation is restricted under the condition of meeting thermal to power ratio; secondly, the scope of gas distributed generation limits to the single building and the investment of the area gas distribution energy projects is restricted; thirdly, due to the replacement of electricity purchase with self-generating electricity, the return on investment of the grid goes down, which affects the enthusiasm of grid enterprises for gas distributed generation to be accessed to the power grid.

4.2 Mechanism barriers

(1) Failure to form a price linkage mechanism

The gas fee is the main operating cost of gas distributed generation, and the electricity and heat sales are the main income. Therefore, the ratio of natural gas price, power generation price and heating (cooling) price affects the investment benefit of the distributed generation directly. Under the established electricity price, the change of natural gas price affect the investment income of distributed generation greatly.

(2) Failure to establish sales mechanism of electricity and heating (cooling)

The electricity and heating (cooling) sales mechanism has not yet been established. Currently, the heating (cooling) price is determined through consulting and negotiating between the investor and the consumer.

(3) Failure to establish the project evaluation and energy efficiency monitoring mechanism

Due to the failure to establish the project evaluation and efficiency monitoring mechanism after the projects are constructed, there is no complete data of established project in our city, thus the accurate operation efficiency and economic benefits cannot be assessed. In the case of the unsound project evaluation mechanism, we can't assess the actual effect of the government subsidies. The discontinuation of some projects lead to the low efficiency of the subsidy funds, and the follow-up supervision work is not really put in place.

4.3 Technical barriers

(1) Lack of project design experience

Summarizing the failure reasons of many previous projects, the lack of design experience is the main technical reason, besides some barriers such as the too high price of the equipment, the rise of the gas price and so on.

1) Incompleted analysis of electricity, heating and cooling loads

As to a distributed generation project, previous investigation and assessment is the main part determining the success of the project. However, during this phase, some planner and designer ignore the special factors of the distributed generation project, and usually determine the system capacity without understanding the actual energy demands. Some of the stopped projects are due to the overlarge system size.

2) Lack of the design standards of the gas distributed energy system

There are two ideas in the design of gas distributed energy system: one is choosing the system capacity under the principle of satisfying the maximum demand; the other is choosing the system capacity under the principle of realizing the "full made full sent" of the distributed energy system according to the minimum demand of energy demand. The former method has big energy conservation and emissions reduction potential, but its system efficiency is low and the economical efficiency is bad, which makes it hard to recycle the equipment investment. The latter one has high system efficiency, good economical efficiency and is easy to be recycled, but it needs accurate measurement and analysis of load, otherwise it also can't meet the requirement of earning of the gas distributed energy system. At present, the country and the local government both have no design standards of the gas distributed energy system to regulate system construction procedure and parameter selection. In the past, most designers choose the big plan, leading to the project design load be too large and the recovered heat is wasted, also the integrated efficiency of the system is low.

(2) The high initial cost of the equipment

The key equipment of distributed power is the prime mover and control device. At present, because the reliability of domestic equipment is low, most of the equipments are imported from abroad. Especially, for the building project, the general single machine capacity is below 1000 kW, the cost of the prime mover may takes up about 50% of total investment. On the other hand, as to the area project, the cost of the prime mover takes up about 30% of total cost.

(3) The high grid-connecting fees

As to the power grid design and engineering related costs, single grid-connecting point is about 40 thousand RMB, and the costs of multiple units and multiple grid-connecting points will grow exponentially. For the costs of gas facilities, when there is ready-made pipe network nearing the project, the costs of gas facilities is about 400000 RMB; if in the vicinity of the project there is no ready-made pipe network, pipe re-arrangement is necessary, and the costs depends on pipe distance, the diameter of pipe etc. For example, when the diameter of pipe is no more than 300 mm, the costs will range from 2~3 million/km RMB (dig expenses is not contained).

(4) The high repair and maintenance fee and unsound service mechanism

The equipments, such as gas turbine, absorption chiller and so on, which were usually used in gas distributed energy system, need regular maintenance and replacement of parts. Absorption chiller, which were basically from domestic manufacturers or foreign brands and joint brands in China, and the maintenance is relatively convenient, and also has formed the industry standard. The parts of gas turbine must be imported, because they are imported equipments. Now because of the expensive price and the high repair cost of parts, the maintenance costs of internal combustion engine unit and gas turbine engine unit are up to 0.08-0.1 RMB/kWh and 0.05-0.08 RMB/kwh, respectively. The long equipment maintenance cycle will lead to the downtime for routine maintenance of equipment in the system, and the average of each machine running 1-3 million hours required for an overhaul, overhaul downtime every 2-3 months, individual overhaul downtime by up to 12 months. Because the overhaul of the imported equipment cannot be made at home at present, the equipment maintenance and maintenance services cannot meet the objective needs.

5. Future prospect of gas distributed generation in Shanghai

The Shanghai municipal government has fully realized the importance of developing distributed energy system. According to "Twelfth five-year plan of the energy development in Shanghai", the energy supply transformation from the centralization to the combination of centralization and distribution and combining with the develop-

ment and application of new technology such as smart grid, promotes the change of the supply method; it will promote the implementation of the distributed power system in the industrial zone and the area of centralized energy use, including hospitals, hotels, business and other key areas and Hongqiao business district, the Shanghai world expo A and B areas, international tourist resort, suburban new town and Jinqiao, Jinshan, Fengxian area, where the new 50-60 projects of gas distributed power system will be constructed and their installed capacity is expected to reach 50MW.

According to "Twelfth five-year plan of fuel gas development in Shanghai", the supply scale of the natural gas in Shanghai strives to achieve 10 billion cubic meters in 2015, realizing the basic balance between supply and demand, carrying out the subsequent resources. The proportion of natural gas in primary energy consumption structure increases to about 11%. The supply scale of liquefied petroleum gas maintains at about 400,000 tones. We should develop the downstream market of natural gas vigorously, and guide the reasonable utilization of natural gas efficiently.

In addition, the "Twelfth five-year plan of electric power development in Shanghai" also points out that we should optimize the structure of power installed in the city, develop gas and other clean energy power generation. And it is necessary to develop the renewable energy power generation, cogeneration and distributed generation in key areas actively, so as to improve overall energy efficiency.

However, the development of gas distributed energy in Shanghai is still not satisfactory when the "Twelfth five-year" is near the end. From the angle of the total energy supply, the gas distributed energy is also difficult to contribute 1% of the total demand for electricity by the end of the "Twelfth five-year". Therefore, it is necessary to put forward medium and long-term development strategy of gas distributed energy in Shanghai, with the guidance of strategic target for the "low carbon and energy-saving global city".

As one of the benchmarking of Shanghai, Tokyo did not put forward the specific development goals of the gas distributed energy. But, under the conservative estimation, it can at least meet medium and long-term development plan of the Japanese government that the generating capacity of the gas distributed energy system accounts for 15% of the total power generation by 2030. Guided by the above goals and considering the current situation in Shanghai, this paper proposes the proportion of the generation capacity of the gas distributed energy system within the whole energy supply will increase 1% every year from the initial stage of "Thirteenth Five-year" plan, and to 25% by 2040.

In order to predict the electric power demand of Shanghai in the next 25 years, this paper further predicts the future demand for electricity based on the forecast of

gross domestic product (GDP), considering the correlation between the demand for electricity and GDP. The growth rate of GDP (5-7%) of Shanghai in recent years is always lower than the national average, even at the bottom in various provinces and cities in the country in 2012. This does not mean that the economic development of Shanghai is falling back, but the economic development in Shanghai has already begun to transition: from the model of economy oriented "total growth" in the past to the model of focusing on the quality of economic development mode of "sustainable development". Therefore, this paper assumes that the economic growth of Shanghai can take "654" development strategy in the next 25 years, namely, to maintain economic growth of 6% in 2020, to maintain the growth rate of 5% between 2020 and 2030, and to maintain the growth rate of 4% from 2030 to 2040. Based on above assumption of the economic growth, meanwhile considering the function relationship between the total economy and the demand for electricity, we can calculate that the total electricity demand is 329.1 billion kWh, which is about 2.4 times of 2012. Table 1 shows the parameter predictions for typical time nodes.

Table 1 The prediction of relevant parameters for the next 25 years in Shanghai

Parameters	2020	2025	2030	2035	2040
GDP (one trillion RMB)	3.2	4.1	5.3	6.4	7.8
Total electricity demand (Billion kWh)	190	221	258	291	329
Share of the gas distributed generation (%)	5	10	15	20	25

In order to calculate the total installed capacity of gas distributed generation, it is necessary to firstly determine the system average annual utilization hours and load rate according to the requirements of the aforementioned generating capacity. The Shanghai government puts forward a threshold value of 2000 hours in the new round of supporting policy in order to improve the subsidy amount; but this value is obviously low, which is difficult to play advantages of energy efficient of gas distributed energy system to the full. In addition, when Japan and Tokyo make the medium-term and long-term plans, annual utilization hours of gas distributed energy system are presumed for 8000 hours; taking off only one month for maintenance downtime every year, this value is relatively ideal. Considering the above situation, this paper assumes that annual utilization hours of gas distributed energy system is for 5000 hours, which covers the winter and summer season and a small number of the spring and autumn. The system load rate, which refers to average load rate of the current value in Japan (42%) and predicted value in 2030 (75%), is assumed to increase in an average annual rate of 1% before 2020, to 45% by 2020, and in an average annual rate of 2% after 2020,

to 85% in 2040.

Therefore, the development path of distributed generation in Shanghai can be calculated in the next 25 years, as shown in Fig. 3. It can be seen from the figure that the gas distributed generation will present the trend of steady growth, with its total installed capacity of 11.89 million kW by 2030 and up to 19.36 million kW by 2040, which corresponds to the total power installed capacity of Shanghai in 2012. At the same time, it also can be seen that annual growth rate of the capacity declines, which is in a strong propulsion phase with average annual growth rate of more than 100% in the initial years, and in the stage of stable development with the annual growth rate of only 4.2% by 2040.

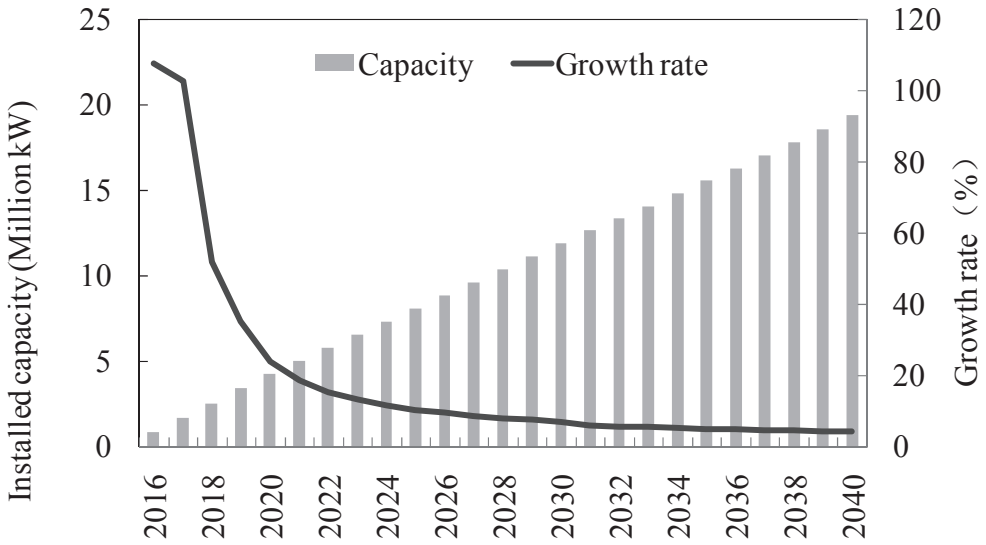

Fig. 3. Future capacity of gas distributed generation in Shanghai

6. Conclusions

As a new type of low-carbon energy system, gas distributed generation is an important part of the development of low-carbon transformation of Shanghai Electric Power industry. And it will certainly play an important role in the future urban supply system in Shanghai. This paper proposed Shanghai's long-term development roadmap of gas distributed energy, basing on the status quo of domestic and foreign research standpoint, while considering the future trend of Shanghai's economic and social development, as well as learning from foreign experience in urban development.

Currently, gas distributed energy development in Shanghai is facing grim situations: on the one hand, most of the prime movers are imported from abroad with relaitvely high initial cost, and the natural gas price increases gradually, which lead to the poor economic performance; on the other hand, the relevant institution, mechanism and policy frameworks are imperfect, making gas distributed energy system difficult to fully enjoy its energy saving advantages. However, considering the huge market potential, it is believed that gas distributed generation will be paid more and more attention, and support the low-carbon transition of the electric power industry in Shanghai.

To achieve the proposed long-term development goal, at the technical level, we should re-examine the gas distributed energy systems, develop some new ideas, and new model of gas distributed energy application. At the policy level, according to specific application background, the existing institutions system, mechanisms system and policy system should be innovated and developed, so as to promote the marketization process of gas distributed energy system.

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